Abstract

The transition from risk factors in the first 1,000 days to childhood obesity occurs largely through the development of maladaptive eating behaviors that emerge early, remain stable, and support greater energy intake over time. We have examined the association between eating behaviors, energy intake, and body composition at 4.5 and 6 years of age among children from the GUSTO (Growing Up in Singapore towards Healthy Outcomes) cohort. Our findings demonstrate that when children select larger portions, eat at a faster rate, and continue to eat when sated, they consume more energy than children who do not exhibit these behaviors. We have shown that these behaviors are stable over time and independently predict higher adiposity and BMI\textsubscript{z} scores at the later time point. We observed that faster eating and greater intakes were associated with parent report measures of appetive traits, such as the child’s satiety responsiveness, food fussiness, and enjoyment of food. Importantly, faster eating rates mediated the link between these appetitive traits and child energy intakes. In addition, within-meal parental feeding practices were linked to a faster eating rate, higher energy intakes, and higher BMI\textsubscript{z} scores in some children, suggesting that parents are aware of these eating behaviors and likely adapt their feeding practices to influence their child’s energy intake. These findings emphasize the need to consider the interaction and cumulative impact of these eating behaviors and parental feeding practices on children’s energy intake, and, consequently, the need to develop holistic intervention approaches that target the behaviors that contribute most to a child’s risk of developing overweight and obesity.
Introduction

Early-life risk factors within the first 1,000 days can cumulatively influence the development of childhood overweight and obesity. Risks such as parental weight status, breastfeeding duration, or the early introduction of solid foods have been associated with weight gain [1], and a recent analysis found that Singaporean children that had 4 or more of these risk factors were 11 times more likely to be overweight or obese at 4 years of age [2]. Associations between the early-life risk and the later development of overweight and obesity are well documented, yet the eating behaviors that support the sustained positive energy balance required for these unhealthy growth outcomes are less clear. The “behavioral susceptibility hypothesis” proposes that a genetic predisposition to become obese manifests through the development of “appetitive traits” linked with greater responsiveness to the food environment and poorer self-regulation that promotes increased energy intake [3]. In this regard, the transition from early-life “risk” to childhood obesity is likely to operate through the emergence of maladaptive eating behaviors that consolidate during childhood, remain stable over time, and predict weight gain and higher adiposity. These behaviors can overlap to influence food choice and energy intakes at every stage of a meal, from portion selection to eating behaviors within the meal, and postmeal appetite and responsivity to available food cues. A child’s food environment, food preferences, habitual energy intake behaviors, and growth outcomes are influenced by their caregivers through the foods they choose and the feeding practices they use [4, 5]. The association between caregiver feeding practices and children’s eating behaviors are likely bidirectional, and the feeding practices used by a caregiver to moderate food intake may also be influenced by the child’s appetitive traits and subsequent eating behaviors displayed [6]. This emphasizes the important role of caregivers and food environment in the behavioral transition from early-life risk to overweight and obesity.

The current paper provides a summary of a series of studies that investigated links between child eating behaviors and parental feeding practices, and their association with energy intake and body composition among children from the GUSTO (Growing Up in Singapore towards Healthy Outcomes) cohort. Since its inception in 2009, the GUSTO cohort has extensively profiled the growth and development of a large sample of Singaporean mother-child pairs ($n = 1,247$). Eligibility criteria and the GUSTO study profile are described in detail elsewhere [7]. The findings reported are summarized from data collected at 2 time points (4.5 and 6 years) and focus on child portion selection, oral processing behaviors, within-meal energy intake, and postmeal measures of food responsivity, as well as measures of parental feeding practices and parent reports of child appetitive traits.
Child Portion Selection and Energy Intake

The amount of food selected at the start of a meal can strongly influence the total amount consumed [8], and although the factors that influence adult portion selection have been studied extensively [9], to date much less is known about how children differentiate between foods, or which factors govern the portion they select [10]. To address this, at the 6-year time point, we asked children (n = 373: 197 boys and 193 girls) to complete a computer-based portion selection task where they made a series of judgments across a range of 8 different foods. Children were required to think about their feelings of hunger and fullness, and they were asked to make estimations of how filling different foods might be, as well as how much they liked them. After this, children estimated the portion of each food they would choose for a meal. They were then provided with one of the foods (fried rice) ad libitum and asked to serve themselves and consume as much or as little as they wanted for lunch. Using this approach, it was possible to compare the relative influence of different premeal beliefs on the portion selected and consumed during the meal [11]. Findings showed that the portions selected by children in the computer task significantly predicted the portion selected and consumed during the lunchtime meal. Children selected larger portions of the foods they liked, but they also appeared to consider the filling properties of different foods by selecting smaller portions of foods they regarded to be more filling and larger portions of foods they believed were less filling independently of how much they liked the food. The amount of food chosen during the lunchtime meal was the strongest predictor of the actual energy intake, with children who selected larger portions eating more, highlighting the tendency for children to eat in response to the portions they are served. These findings are important as they demonstrate that children at this age are not simply choosing larger portions of foods they like but are also capable of discriminating between foods based on their filling properties. The tendency to select larger portions at this age is linked with greater energy consumption, supporting the idea that guiding appropriate food portion selection is an important locus in the control of a child’s energy intake.

Eating Rate and Energy Intake at 4.5 and 6 Years

Although children’s appetitive traits are expressed through their premeal portion decisions, they can also be seen in the oral processing behaviors they exhibit within a meal. Previous research has demonstrated associations between the oral processing behaviors that promote greater energy intakes within a meal.
and child BMI [12, 13]. To further investigate these links between portion selection, oral processing behaviors, and energy intake, children at both 4.5 and 6 years participated in an ad libitum lunchtime meal ($n = 263$: 133 boys and 130 girls) as a measure of their usual energy intakes. The test meals were video recorded at both time points, and using behavioral coding we derived a series of oral processing behaviors for comparison with energy intake based on a previously published approach [14]. Figure 1 shows an exemplary screenshot of a video recording and a coding scheme used. This approach enabled a comparison of differences in the oral processing behaviors exhibited during the meal to explore whether these behaviors were associated with differences in child energy intakes and body composition at each time point.

Children who ate their meal at a faster rate (g/min) consumed significantly more energy than children who ate their meal slower [15] (Fig. 2). However, eating rate was specific to the time children had food in their mouth, and a comparison of the joint impact of eating rate and total meal duration (min) showed that the children who ate faster and for a longer duration consumed the most energy.

Closer inspection of the oral processing characteristics exhibited by faster-eating children showed that children who eat faster tend to have a larger average bite size (g), chewing each bite in fewer cycles and through this producing a
shorter average orosensory exposure to the food during each mouthful (Fig. 3). Comparison of microstructural patterns of eating at the 6-year time point demonstrated that the same oral processing behaviors were driving faster eating rates and greater energy intakes at both time points in what we have described as an “obesogenic” eating style that encourages greater food intake within a meal [16].

When children were median split into faster- and slower-eating groups at 4.5 years, we found that children in the faster-eating group consumed on average
75% more energy within the same lunchtime meal than children in the slower group [15]. These acute differences in energy intake were also associated with differences in child body composition at 4.5 years, as children in the faster-eating group had significantly higher BMI-z scores and higher skinfold adiposity indices, and a subset of children who had abdominal MRI scan ($n = 158$) had a higher volume of subcutaneous abdominal adiposity [15]. When the same children were followed to the 6-year time point, it was clear that these behaviors remained stable and again predicted greater energy intake during the lunchtime meal. Being a faster eater at 4.5 years was a significant predictor of being a faster eater at 6 years, and children who ate faster at 4.5 years had higher BMI-z scores and adiposity at 6 years [17]. These findings emphasize the stability of oral processing behaviors and the importance of these behaviors in promoting greater energy intake and weight gain.

The selection of larger portions and eating at a faster rate were both significant independent predictors of higher energy intakes among children. However, these eating behaviors were also found to interact, such that children who chose larger portions and ate at a faster rate consumed the most energy within the meal [18], highlighting the combined impact of larger portions and eating quickly in promoting energy intake. Interventions focused on reducing eating rate alone may have limited success if they do not also account for the risk of increased energy intake arising from the selection of larger portions. Specific oral processing behaviors, such as a large bite size, appear to be stable over time and, when observed in children at 4.5 years, were capable of predicting changes in body composition at the later time point. Taken together, these findings are important because they suggest several loci for potential intervention, where it may be possible to reduce the impact of multiple behaviors on energy intakes both in terms of monitoring child-selected portions and potentially using meal properties, such as food textures, to target the specific oral processing behaviors that promote faster eating [19]. Considering the independent and combined impact of these overlapping behavioral risks, intervention strategies should take an integrated approach accounting for both premeal portion selection and within-meal eating behavior to control both energy selection and intake [18].

**Eating in the Absence of Hunger and Child Inhibitory Control**

Beyond main meals, children are susceptible to increase their energy intake when palatable snacks are available in their food environment even when a child is fully sated. The tendency to eat in the absence of hunger (EAH) is a measure of food cue responsivity and has previously been shown to contribute to the in-
creased energy intakes associated with overweight and obesity among children [20]. To study differences in EAH among GUSTO children, a subset (n = 255: 127 boys and 128 girls) were given free access to snacks after they reported feeling full following the lunchtime meal at both the 4.5- and 6-year time points. Children were classified into those that did or did not exhibit EAH behaviors, and the quantity of calories consumed from their snack intake during the EAH task was recorded. Results showed that children who demonstrated EAH did not differ in the energy consumed at lunch from children who did not show EAH. However, children who demonstrated EAH consumed more energy cumulatively when intake was combined from the lunch and the EAH snack test at both 4.5 and 6 years [21]. In addition, children who exhibited EAH at the earlier time point were 3 times more likely to continue this behavior at the 6-year time point, indicating consistency in this behavior and a potential sustained contribution to greater energy intakes. Despite this, there was no association between children’s tendency to EAH and their BMI or adiposity at either time point, suggesting the link between EAH and child growth outcomes might manifest at an older age.

The eating behaviors we have identified to predict higher energy intakes tend to be stable over time and often overlap within the same group of children. This may be due to common underlying mechanisms that predispose some children to be more vulnerable to increased energy intakes than others. For example, children who show EAH may be less able to control an impulse to respond to food cues even when sated. Previous research has shown that children who have higher inhibitory control are less likely to be overweight than children who do not show the same capacity for self-regulation [22]. In the context of eating behavior, inhibitory control relates to the ability to stop or suppress certain responses to food cues in the environment. A higher propensity to EAH is a good behavioral measure of a child’s responsiveness to food cues and may be one of the mechanisms through which a lower inhibitory control predisposes children to increase their energy intake and eventually promote weight gain [23]. We investigated whether individual differences in inhibitory control were linked to the identified differences in child eating behaviors that promote greater intake, such as the selection of larger portions, faster eating rates, and EAH. Children at 6 years completed a measure of inhibitory control known as the stop signal task, which gauges a child’s capacity to voluntarily inhibit or regulate their attentional and behavioral responses (CANTAB; Cambridge Cognition 2017). Children that had lower inhibitory control and were more restless during the stop signal task were the same children that tended to EAH, suggesting a relationship between this trait and energy intakes from snacks [24]. Importantly, further associations were found where children with lower inhibitory control also selected larger food portions on the computer portion task and ate food at a faster rate.
during the meal [24]. These results suggest a convergence of some eating behaviors associated with greater energy intakes among children with lower inhibitory control that reflects the way they select and consume their portions and respond to food cues in their environment. This overlap in behaviors is predicted to drive weight gain, and identifying children with lower inhibitory control and the associated food intake behaviors may help in the development of strategies to mitigate this obesity risk.

### Parental Influences on Child Eating Behaviors and Energy Intake

A wide range of eating behaviors have been shown to increase children’s energy intakes and promote weight gain, and it is important to consider that these behaviors emerge in the home food environment, where one of the strongest factors shaping their development and expression is the influence of a child’s caregivers. During the preschool years, parent’s dietary habits, portion selection, and feeding practices around mealtimes play a significant role in influencing children’s experience with foods, which in turn shapes their eating behaviors. For example, the additional energy consumed when children have the opportunity to eat additional healthy snacks relies on these snacks being made available in the child’s food environment in the first place. Moreover, energy intake from EAH is likely to be moderated by the caregiver’s feeding practices. The foods and portions a parent or caregiver selects for their child can significantly influence energy intake, with larger portions promoting greater consumption [25]. When parents in our cohort were asked to choose portions for their child, they tended to select larger portions for meals they had chosen in large portions for themselves, and they picked larger portions for their child if they believed the child liked that food [11]. This indicates that parents may base portion choices for their child on their own beliefs about foods and rely less on adapting portions to their child’s needs. This raises concerns that parental biases towards selecting larger portions for themselves may translate into habitually selecting larger portions for their child, which in turn may influence a child’s longer-term perception of appropriate portion size [10].

In addition to selecting a child’s food and portions, parents often use feeding practices during mealtimes to encourage, modify, or restrict food intake. Research has shown that restricting energy-dense palatable foods and using more controlling feeding practices can be counterproductive and lead to higher energy intakes and weight gain over time [26]. We investigated whether parents in our cohort were aware of their child’s appetitive traits. Parents who reported their child to have higher food approach (enjoyment of food or food responsiveness—

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ness) and lower food avoidance (i.e., satiety responsiveness and fussy eating) behaviors had children who consistently consumed greater energy and had higher BMI, and adiposity scores [27]. Faster eating rates were found to mediate the relationship between appetitive traits and higher energy intakes, such that children who had traits associated with greater energy intakes consumed more energy when they also ate at a faster rate [28]. This finding suggests that eating rate may be one of the behavioral pathways through which stronger appetitive traits manifest to promote energy intakes, and that mothers are noticing these behaviors in their children.

Finding that parents are somewhat aware of the eating behaviors linked to certain appetitive traits in their children suggests that they might use their feeding practices to try and modify them. Therefore, we investigated whether mothers’ use of feeding practices was linked with their child’s oral processing behaviors and increased energy intakes. To do this, we explored the relationship between the type and frequency of parental feeding practices (e.g., prompts, restrictions, and encouragements) and child eating behavior in a subset (n = 155) of child-mother pairs [29]. Children that experienced the most frequent feeding practices during the meal ate at a faster rate and consumed significantly more energy than children who experienced less-frequent feeding practices. However, this was not the same across both genders, as girls who displayed faster eating rates were more likely to experience parental feeding practices than boys who exhibited the same eating style. The frequency of parental feeding practices and child faster eating rates independently predicted greater energy intakes; however, children who ate faster and also experienced the highest frequency of feeding practices had the greatest energy intakes, suggesting that parental influence did little to reduce eating rate or energy intake within the meal. This remained the case at 6 years, where prospective analyses showed that those children who were more frequently prompted at age 4.5 years had continued to have faster eating rates at 6 years [29].

Taken together, these findings stress the importance of considering how parental influences can impact the child’s food environment and moderate the expression of eating behaviors associated with greater energy intakes. Caregivers can have a powerful short-term impact on their child’s energy consumption and the potential to exert a longer-term impact on the development of child food and portion selection, as well as the eating styles that can increase energy intake within meals [29]. Rather than selecting portions and encouraging intake based on the parent’s feeding goals, parents are encouraged to apply responsive feeding practices where appropriate foods are provided based on awareness of and sensitivity to a child’s appetite need state [10].
Conclusions: Future Opportunities for Integrated Behavioral Interventions

Our findings highlight associations between higher energy intakes and a series of overlapping and interrelated eating behaviors and parental feeding practices. We have identified behaviors such as selecting large portions, eating at a faster rate, and EAH consistently predicted greater energy intakes. An opportunity exists to moderate energy intakes by providing guidance to parents and children on the appropriate portions to select or by reducing the availability of larger portions for children in general. Insights into the oral processing behaviors that underpin faster eating rates create new opportunities to develop foods that encourage smaller bite size, increase chews per bite, and result in a natural slowing of eating rates in response to the food textures experienced during consumption [30, 31]. Future research should consider combining approaches in the design of food portions and textures for children with appetitive traits and eating behaviors that increase their risk of increased energy intakes over time.

The eating behaviors identified have been shown to independently predict higher energy intakes, but when combined they often increase the risk of energy overconsumption and subsequent weight gain. Each risk in isolation may periodically lead to a positive energy balance, but, cumulatively, these risks combine to sustain a positive energy balance and promote increased weight gain throughout childhood. The interplay between eating behaviors and feeding practices is important to consider, and it highlights the potential for aberrant eating behaviors to be exacerbated when energy intake is informed by factors unrelated to a child’s appetite need state. Understanding how portion selection and eating behavior is moderated by parental feeding practices can help improve our ability to identify children at risk of developing obesity and advance the development of integrated approaches that target specific elements of a child’s behavior, their food environment, and their parent’s feeding practices.

The eating behaviors and feeding practices discussed in the current chapter can each contribute to increases in energy intakes, but in combination they are likely to have the greatest impact on energy intake, e.g., to consume quickly larger portions of higher-energy-dense foods. Attempts to modify a child’s eating rate are likely to be unsuccessful if they do not also consider the portion selection or parental feeding practices that also encourage greater energy intake within meals. These findings underscore the need to go beyond targeting individual eating behaviors and to consider holistic interventions that focus on the cumulative impact of energy selection, eating styles, and feeding practices that moderate these behavioral outcomes in the child.
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